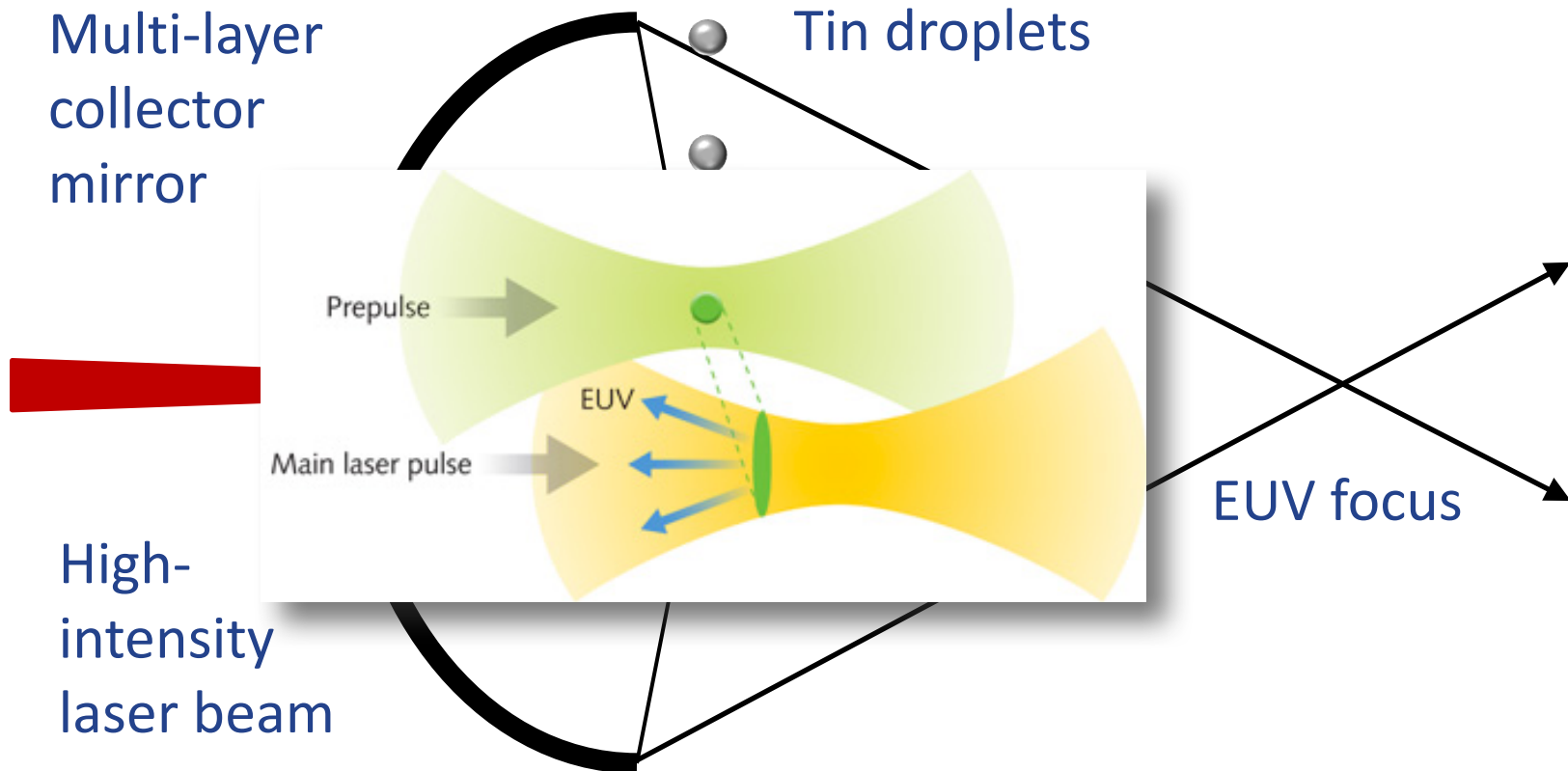




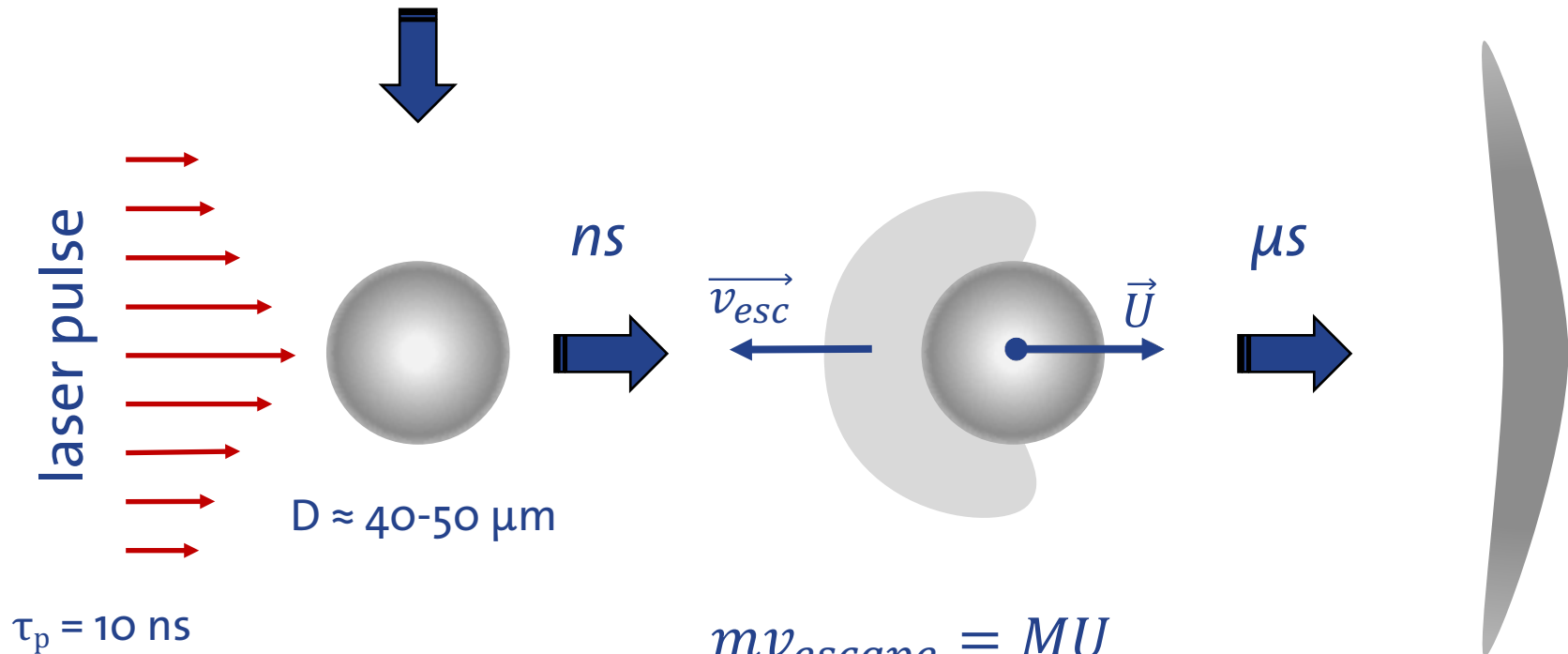
Dynamics of a metallic microdroplet upon interaction with nanosecond laser pulse

D. Kurilovich, A. Klein, F. Torretti, M. Noordam, J. Scheers,
W. Ubachs, R.A. Hoekstra, H. Gelderblom, O.O. Versolato

Droplet-based LPP EUV source



Laser impact on metallic microdroplets



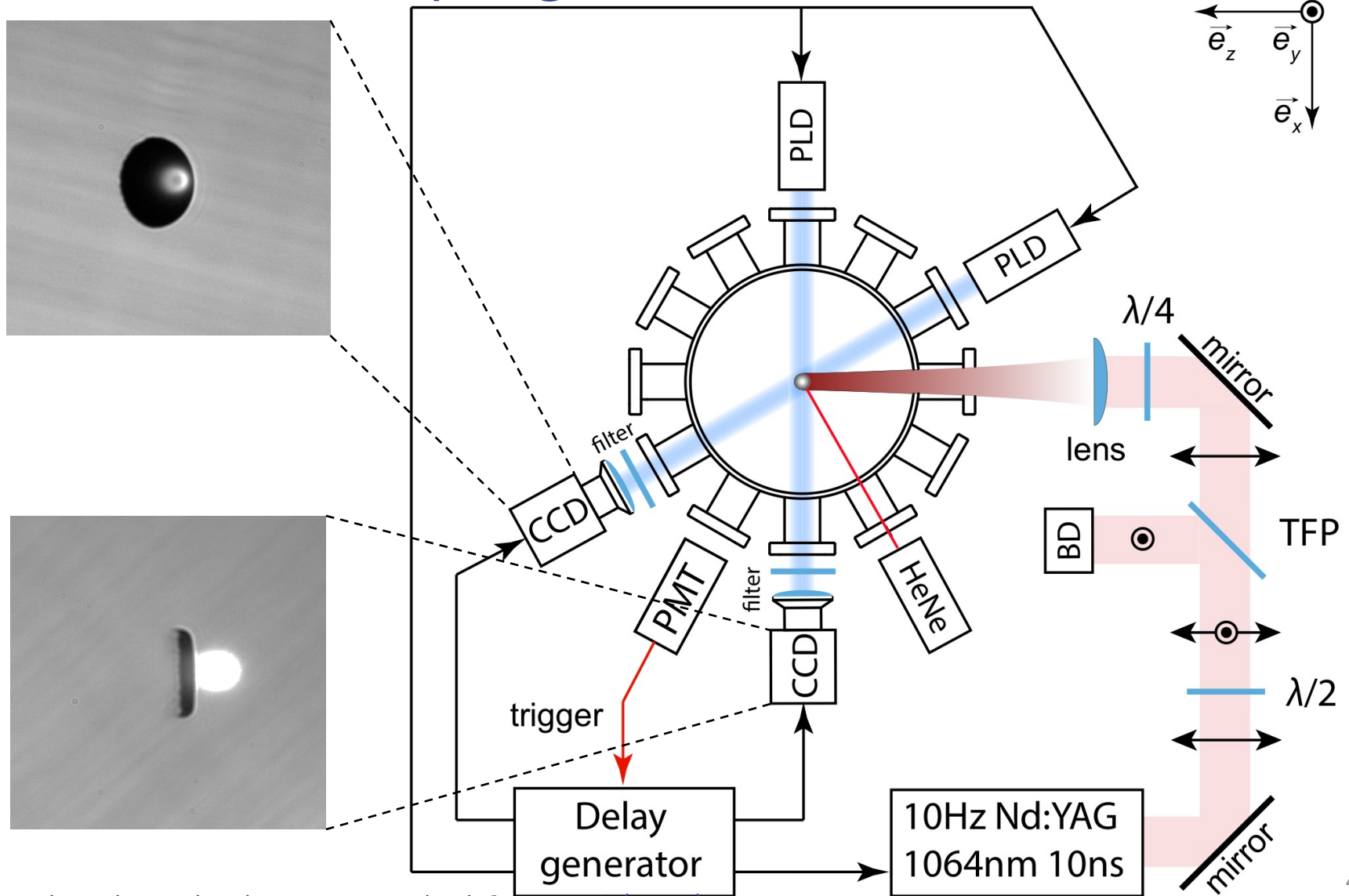
$$mv_{escape} = MU$$

$$v_{escape} \approx 5 - 15 \text{ km/s}$$

$$m \approx 1\text{‰} - 1\% M$$

Experimental setup

- based on tin droplet generator and Nd:YAG laser

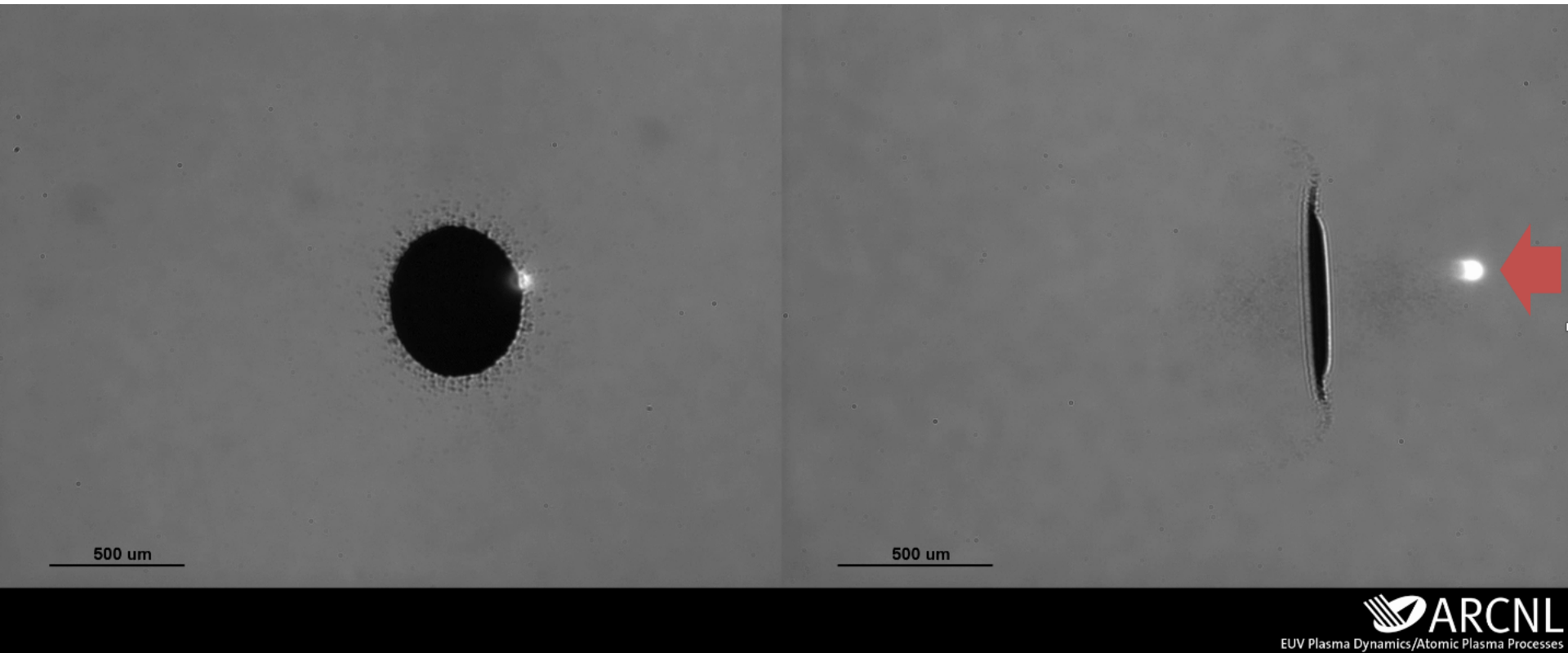


Shadowgraph imaging

Each frame represents a fresh droplet

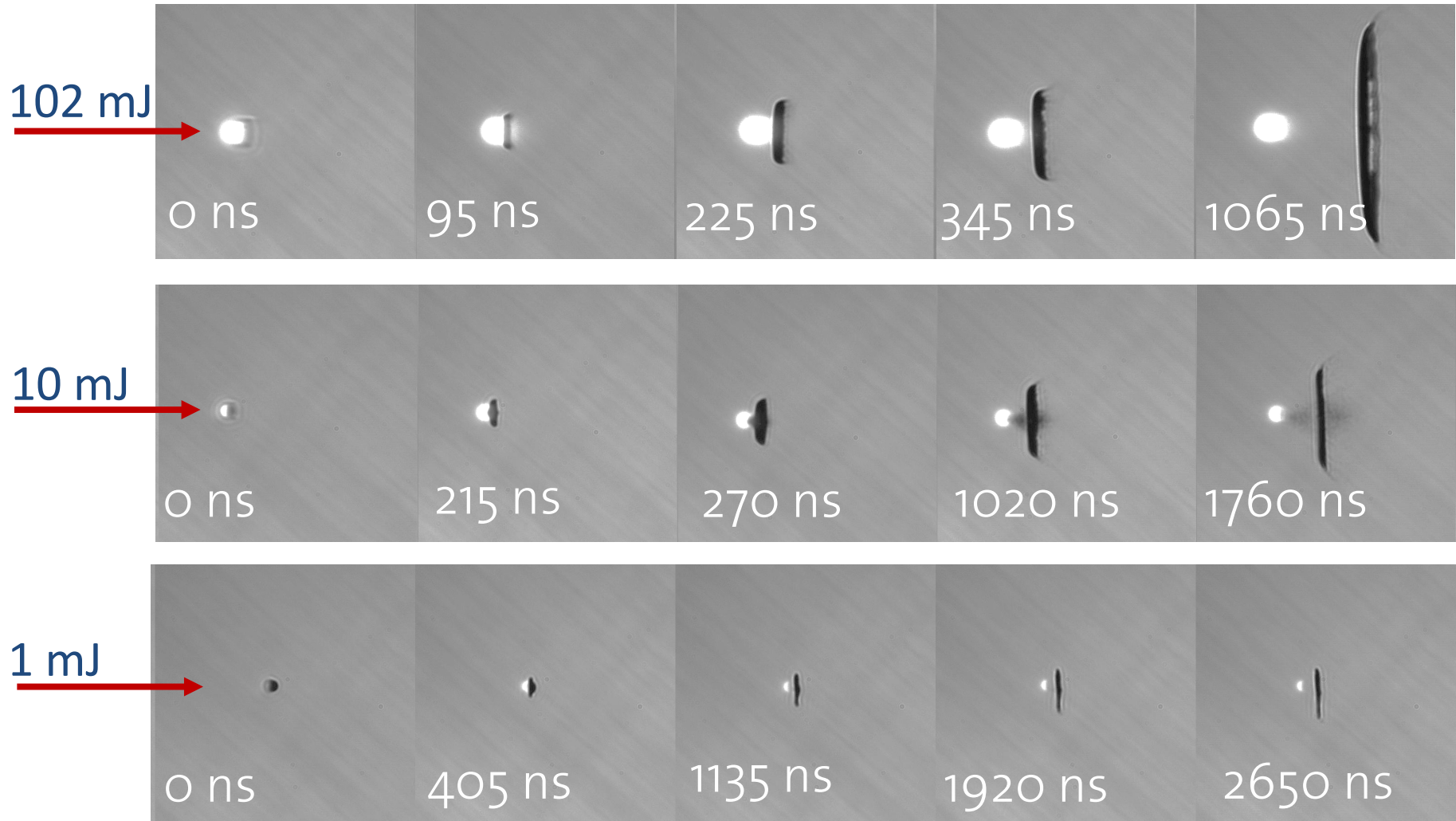
Front view (30°)

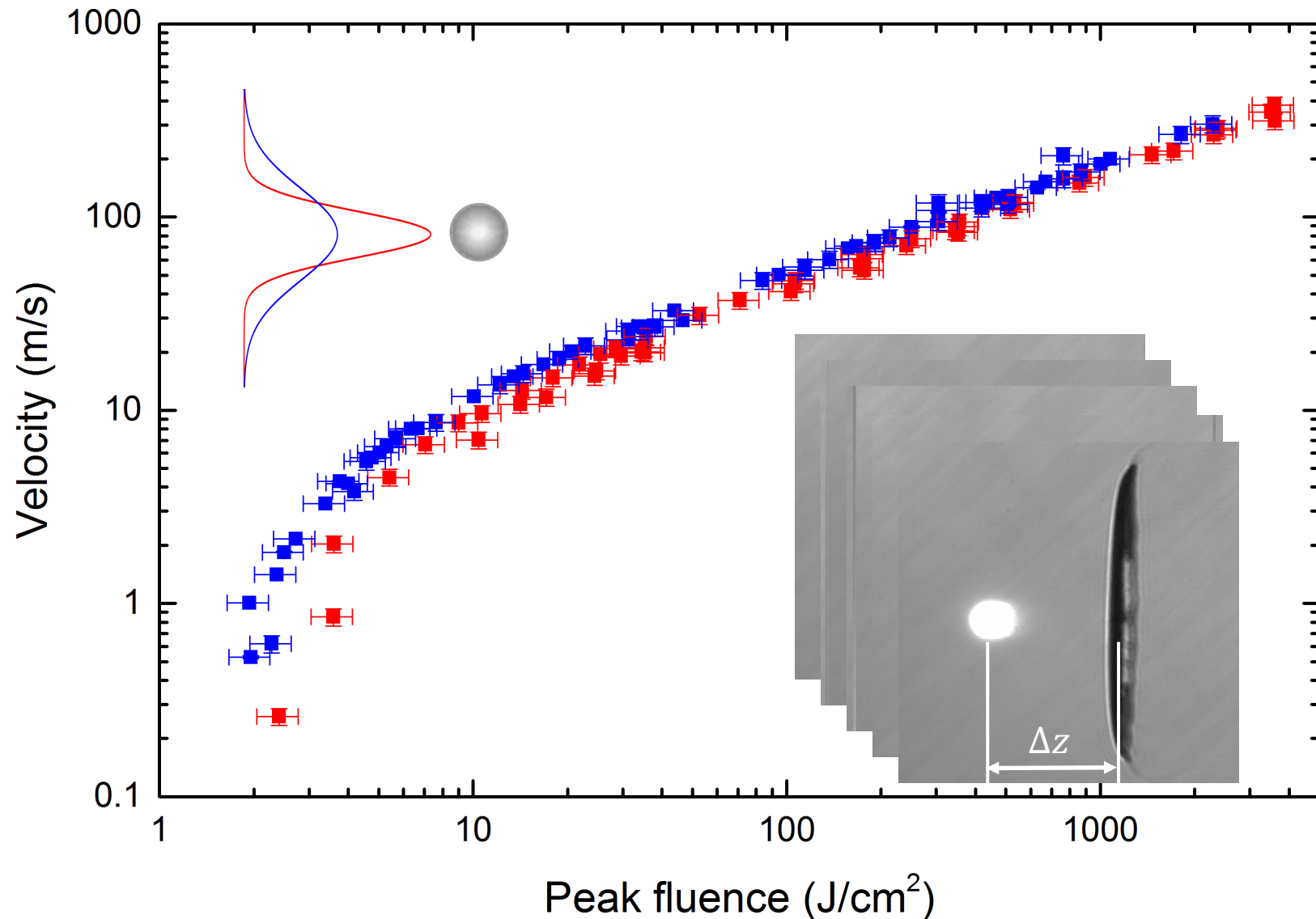
Side view (90°)

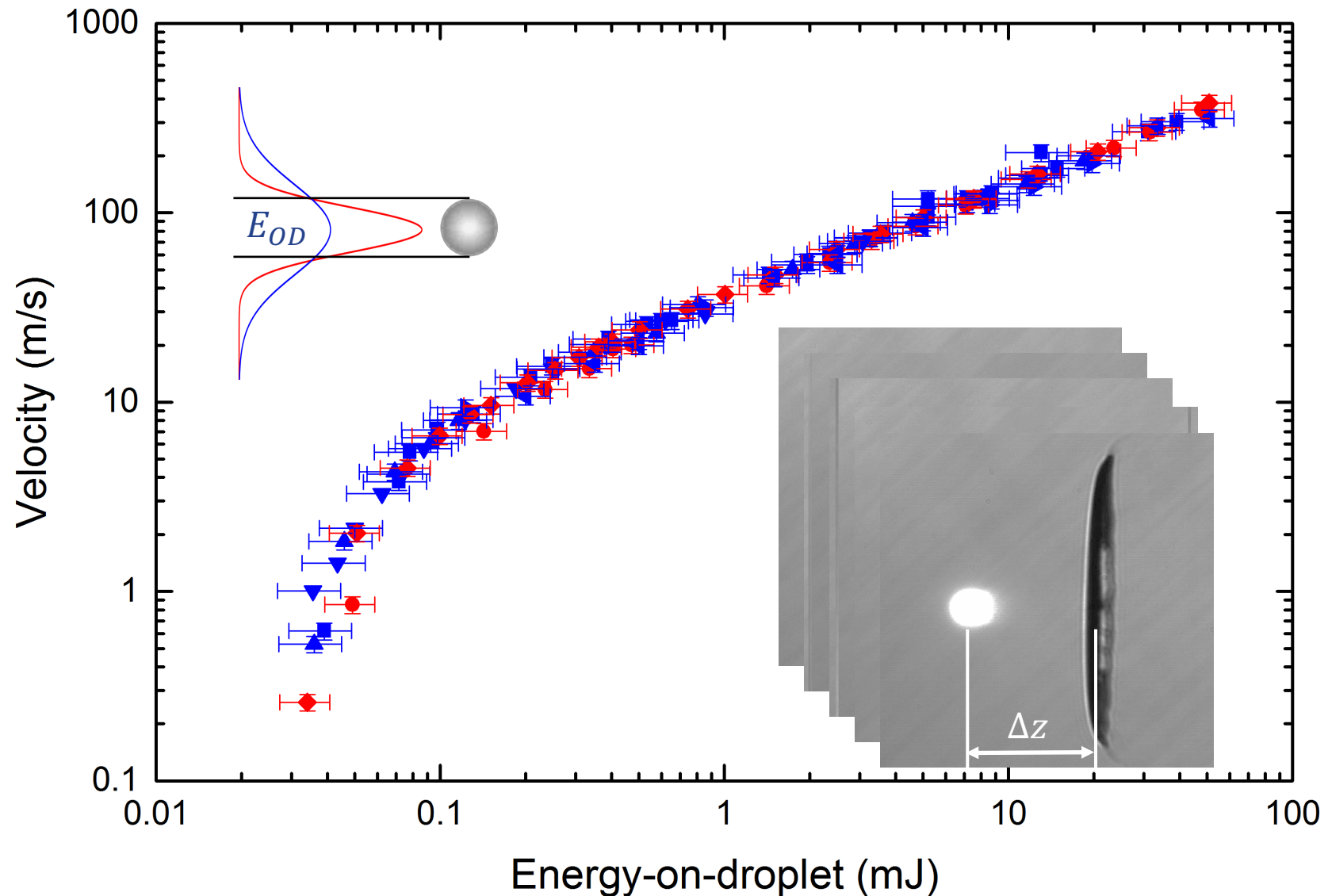


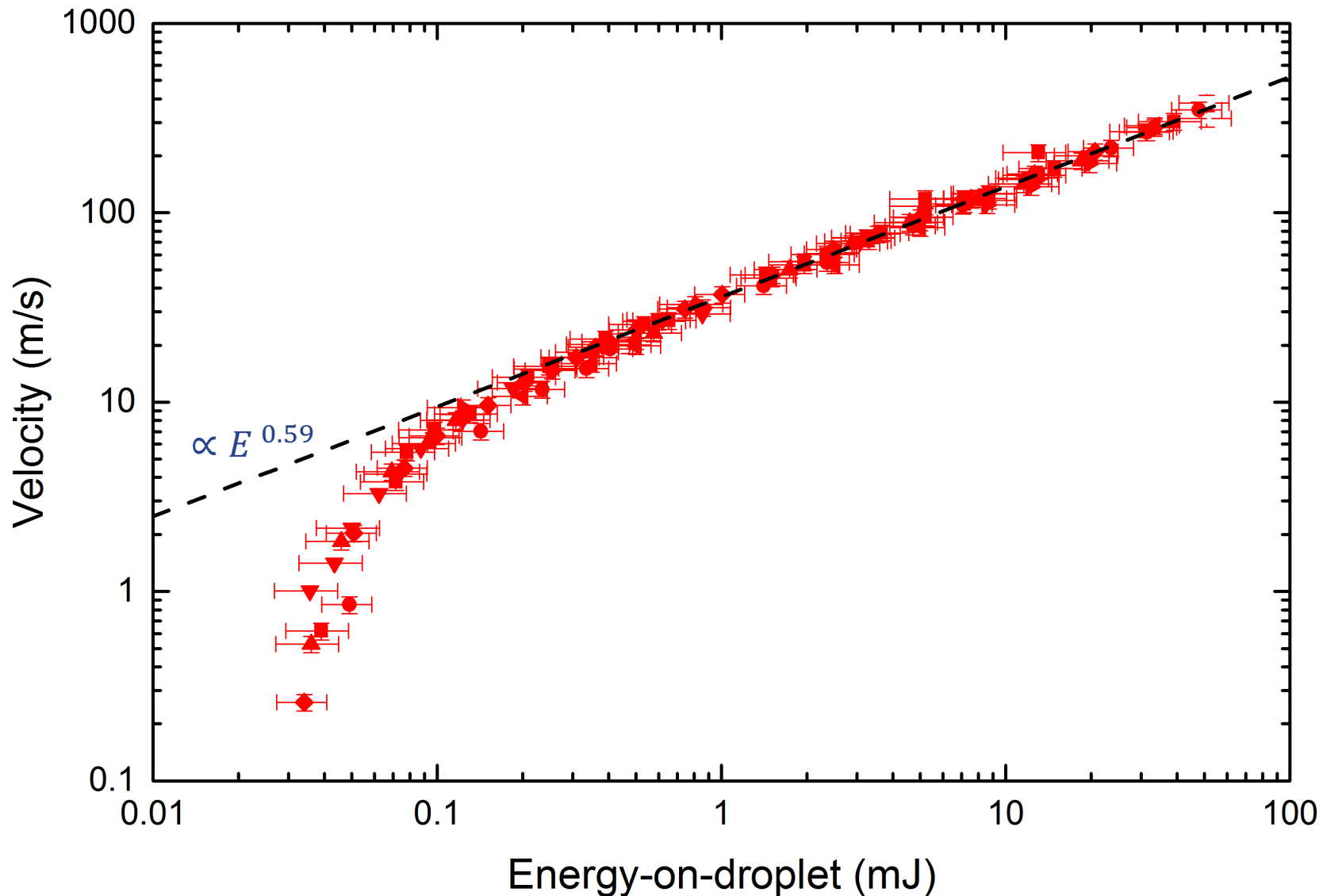
Droplet propulsion and deformation ARCNL

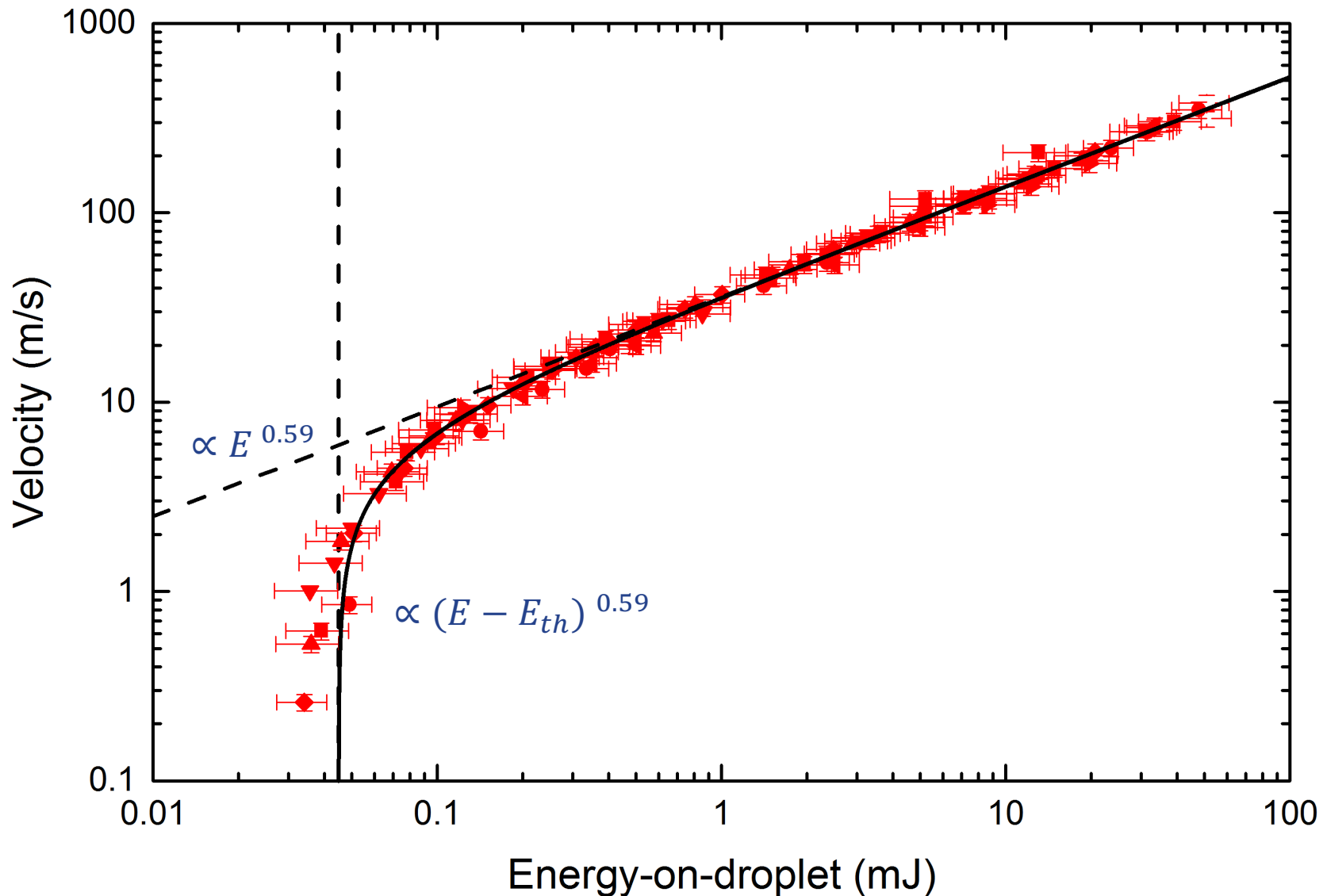
Study of the process

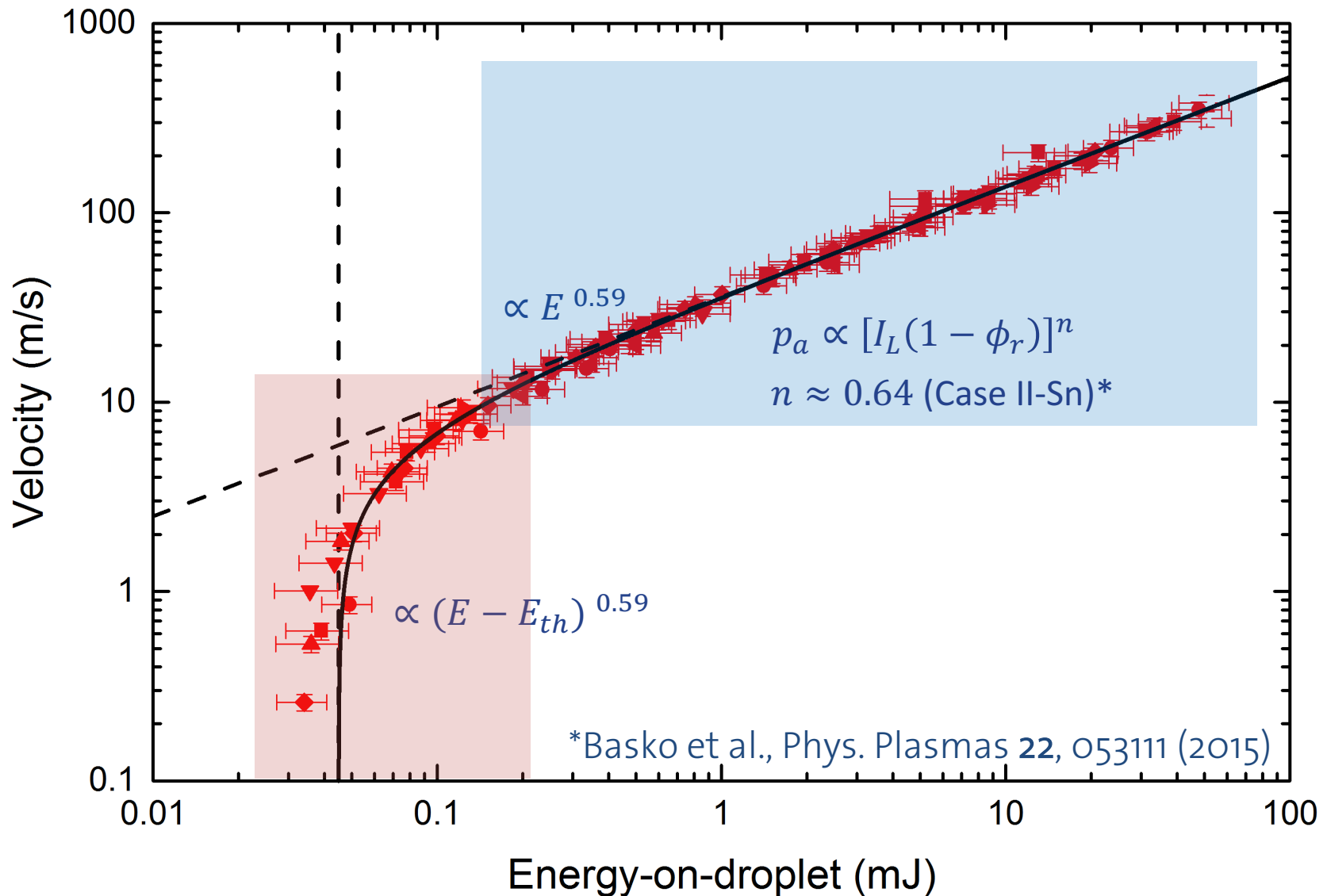












Threshold of ablation

Threshold of ablation:

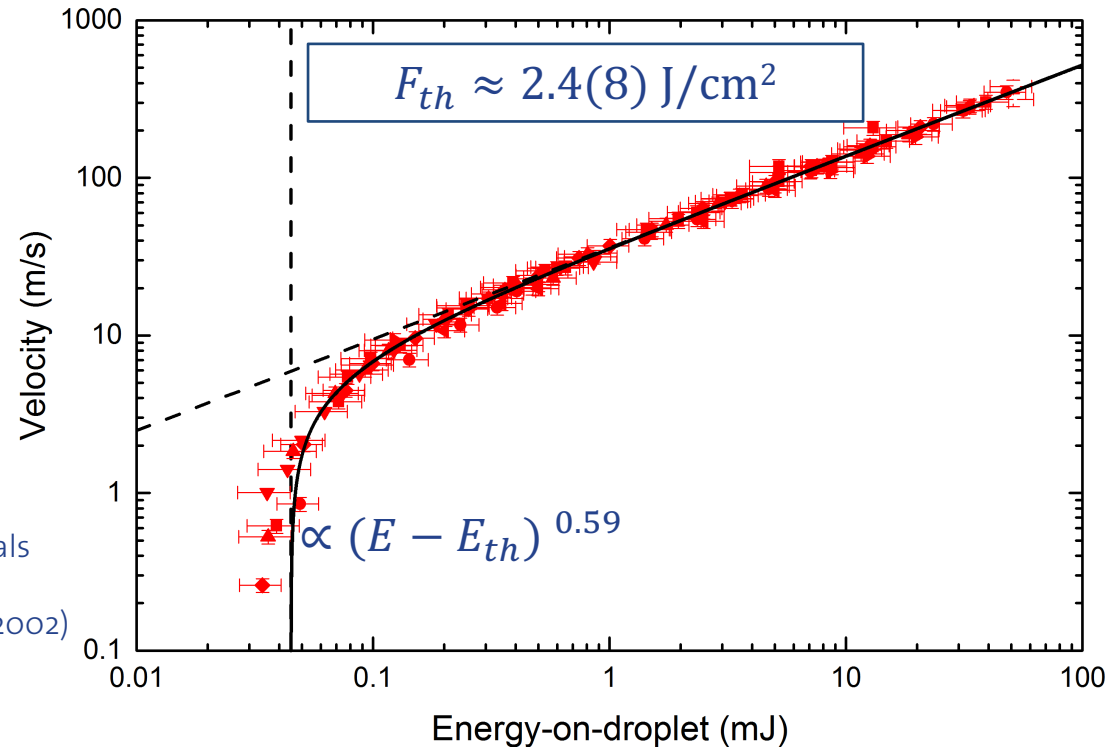
$$F_{th} = \rho \Delta H \sqrt{\kappa \tau_p} \approx 0.63 \text{ J/cm}^2$$

$$A = 1 - \mathcal{R} \approx 10 - 20\%$$

$$\widetilde{F}_{th} \approx 5 \text{ J/cm}^2$$

B. N. Chichkov, et al., Applied Physics A: Materials Science & Processing **63**, 109 (1996)

E. G. Gamaly, et al., Physics of Plasmas **9**, 949 (2002)



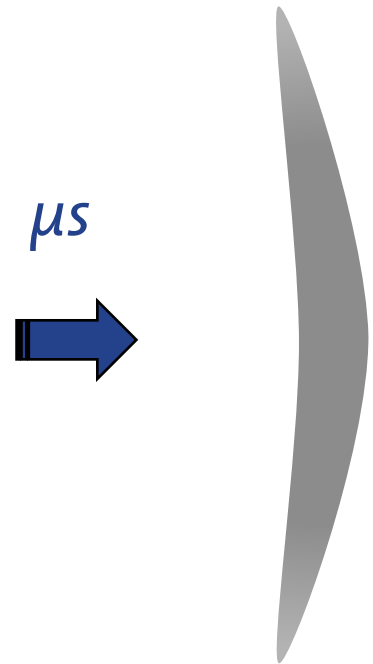
Other estimates:

$$F_{th} \approx 5 \text{ J/cm}^2$$

M. Masnavi, et al., J Appl. Phys. **109**, 123306 (2011)

D. Kurilovich et al., Phys. Rev. Applied **6**, 014018 (2016)

Laser impact on metallic microdroplets



Propulsion leads to deformation

In-Sn droplet deformed by circularly polarized laser light

$$\tau_p \leq \tau_a \ll \tau_i < \tau_c$$

$$\tau_c = \sqrt{\rho R_0^3 / \gamma} \cong 14 \mu s$$

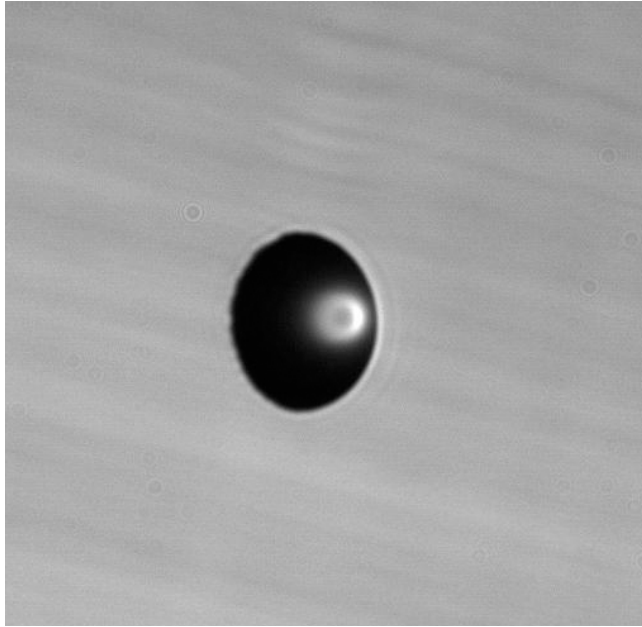
$$\tau_i = R_0 / U \cong 2.5 \mu s$$

$$\tau_a \approx \text{few } 10 \text{ ns}$$

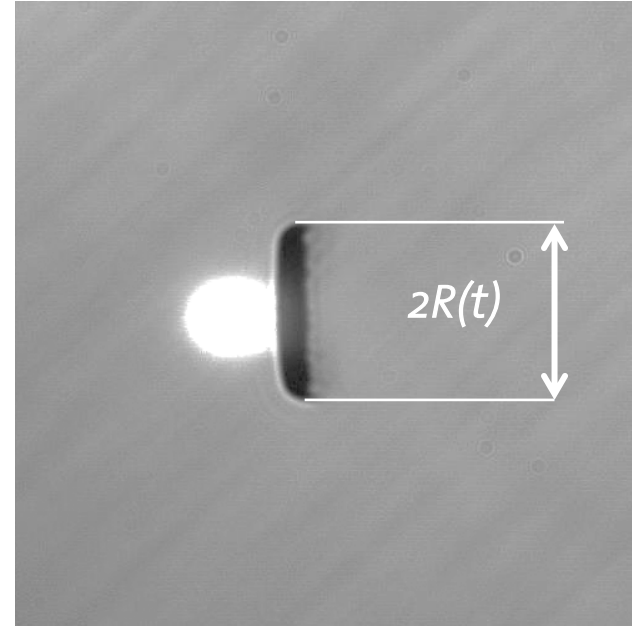
$$\tau_p = 10 \text{ ns}$$

Propulsion leads to deformation

In-Sn droplet deformed by circularly polarized laser light



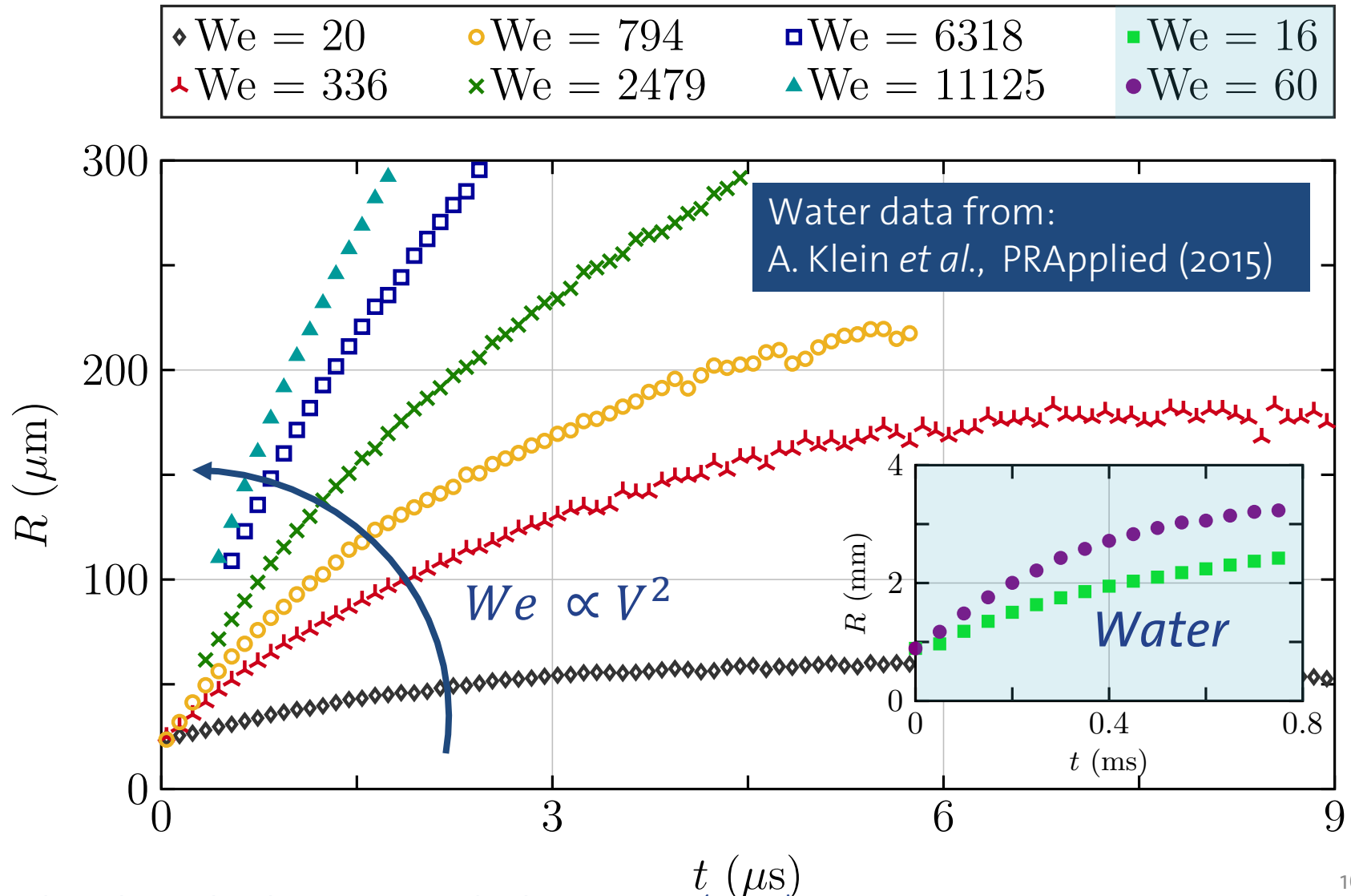
30° projection



90° projection

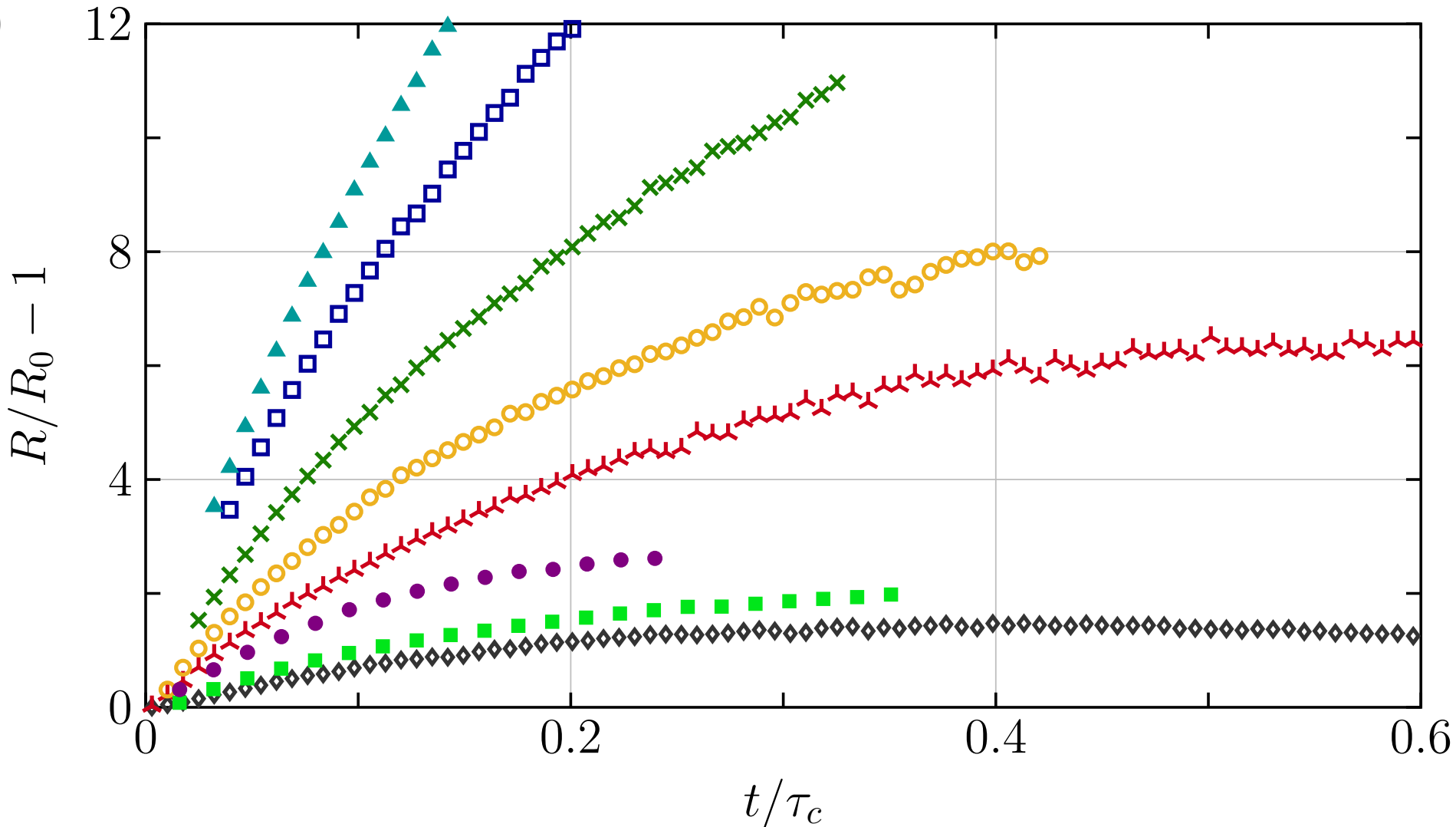
Propulsion leads to deformation

Scalability of hydrodynamic response from H_2O to In-Sn



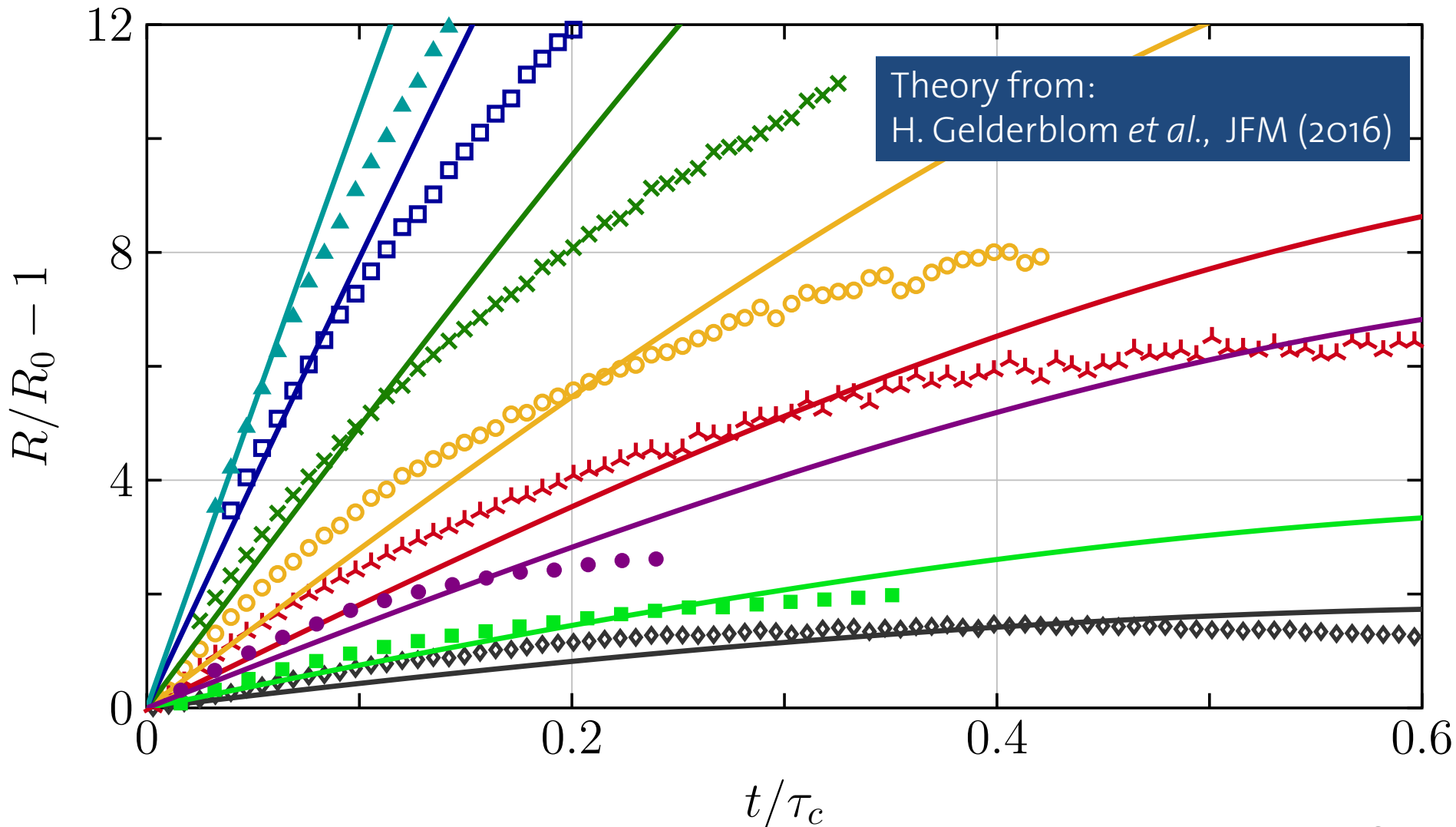
Propulsion leads to deformation

Scalability of hydrodynamic response from H_2O to In-Sn



Propulsion leads to deformation

Scalability of hydrodynamic response from H_2O to $In-Sn$



Acknowledgments



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Wim Ubachs



Ronnie Hoekstra



Oscar
Versolato



Thomas Cohen
Stuart



Francesco
Torretti



Joris Scheers



Ruben Schupp

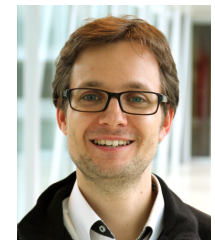


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Hanneke
Gelderblom



Alexander
Klein





Thank you
for your attention!